CM-232
Project 2.16
C2130

ANALYSIS OF HEAVY METALS IN SEDIMENTS FROM INDIAN RIVER/MOSQUITO LAGOON STORMWATER OUTFALLS

Final Report for
Contract No. CM-232

Environmental Management Department
County of Volusia

Project Manager: Randall K. Sleister

December 1989

Funds for this project were provided by the Department of Environmental Regulation, Office of Coastal Management using funds made available through the National Oceanic and Atmospheric Administration under the Coastal Zone Management Act of 1972, as amended, and by the County of Volusia.

EXECUTIVE SUMMARY

Sediments from the three major stormwater outfalls discharging into the Indian River/Mosquito Lagoon and one control station were sampled for metal concentrations during 1989. The samples were analyzed for aluminum, arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc.

Utilizing procedures outlined by the Florida Department of Environmental Regulation, the natural relationship of metals and aluminum were used to determine if the sediments collected from the stormwater outfalls had been enriched from anthropogenic sources.

Concentrations were found to be within the predicted limits for arsenic, cadmium, chromium, and nickel. ~~Elevated~~ concentrations of lead were found at ~~all of the stations~~ with the exception of the background station. The sediments of the stormwater outfall serving New Symrna Beach had elevated concentrations of lead, copper and zinc. Elevated zinc concentrations were also found at the outfall of the Edgewater canal.

This project demonstrates the Indian River and the Mosquito Lagoon is receiving heavy metal contamination from the stormwater drainage systems within Volusia County and the Cities of New Symrna Beach and Edgewater. Modifications of the stormwater systems is needed to mitigate the potentially adverse impacts of this pollutant loading.

ACKNOWLEDGEMENTS

The project manager appreciates and wishes to acknowledge these individuals for their technical and moral support, editorial review and comments during all or part of this study:

Volusia County
Environmental Management Department

Karen Duhring
Elizabeth Edgar
Tim Egan
Chryl Fox
Mike Gately
Fred Jurick, Marine Extension Agent

Florida Department of
Environmental Regulation

Fred Calder
Steven Schropp

LIST OF FIGURES

<u>LIST OF TABLES</u>

ANALYSIS OF HEAVY METALS IN SEDIMENTS
FROM INDIAN RIVER/MOSQUITO LAGOON STORMWATER OUTFALLS

INTRODUCTION

The Surface Water Improvement and Management (SWIM) Act of 1987 (Chapter 373.451-373.4595, Florida Statutes) was enacted to protect Florida's natural surface water systems from further degradation due to point and nonpoint pollution. The Indian River Lagoon was identified as a priority water body in the SWIM Act and the St. Johns River (SJRWMD) and South Florida Water Management Districts (SFWMD) have compiled a management plan for this estuary.

One of the primary goals of the SWIM Plan is "to attain and maintain water and sediment of sufficient quality ("...Class III or better...", Chapter 373.453, F.S.) in order to support a healthy, macrophyte-based, estuarine lagoon ecosystem" (SWIM,1989). Pursuant to this plan, a Water Quality Monitoring Network was implemented for the entire Indian River Lagoon system. Approximately 150 long-term sampling stations from New Smyrna Beach to Hobe Sound in Palm Beach County were established through the cooperative efforts of Volusia County, Brevard County, DER, SJRWMD, SFWMD and Florida Institute of Technology.

Mosquito Lagoon in Volusia and Brevard County is the northernmost feature of the Indian River Lagoon system. This water body was identified as a problem area in the SWIM Plan due to degrading water quality and the existing Class II designation. These Class II waters were recently downgraded from "Approved" to "Conditionally Approved" for shellfish harvesting because of bacteriological conditions. Since this is one of the last remaining Class II areas, initiatives to evaluate the causes and extent of degradation are critical.

The Mosquito Lagoon Watershed Action Committee includes representatives from local governments and interest groups who share concern for Mosquito Lagoon. This committee has provided an interagency mechanism for discussing water quality and stormwater management problems. The main objectives of this committee are to implement uniform standards and ordinances throughout the lagoon's watershed and to establish long-term monitoring programs.

The Volusia County Environmental Management Department (EMD) started a water quality monitoring program for Mosquito Lagoon in 1988. Twenty stations, ranging from New Smyrna Beach south to the Volusia-Brevard County line, are sampled monthly. Field measurements taken at each station are total depth, water temperature, pH, dissolved oxygen, conductivity, salinity and light penetration. Lab analysis includes total non-filterable residue, turbidity, color, chlorophyll, nitrate-nitrite, ortho-phosphate, total Kjeldahl nitrogen and total phosphorus.

Additional monitoring currently involves field measurements and lab analysis of stormwater from seven stations in the Edgewater Canal drainage system. This sampling is conducted monthly. In addition to the parameters listed above, these water samples are analyzed for lead, copper and zinc.

Sediment analysis is also important for assessing pollutant loadings in estuaries. Some pollutants carried by freshwater tributaries and stormwater are removed from the water column when the freshwater mixes with saltwater in the estuary (Martin & Whitfield, 1983). Analyzing water samples alone will not account for pollutants incorporated in the sediments, particularly heavy metals.

More than 80% of the annual heavy metal loading to Florida surface waters comes from stormwater. Urban stormwater normally carries several heavy metals, including lead, zinc, copper, nickel, iron, cadmium and chromium (Burke, 1983). The primary sources of these metals are cars and trucks. Other anthropogenic sources of metals into estuaries are industrial and commercial point discharges, galvanized metals and anti-fouling paints (Trefry et al., 1983).

The Florida Department of Environmental Regulation (DER) developed guidelines to determine whether a particular metal concentration is indicative of natural or contaminated sediment (DER, 1988). This technique is based on the relatively constant ratio between aluminum and other metals in continental rock. Aluminum is commonly used to normalize metal concentrations because it is naturally abundant and there are only trace amounts of aluminum in anthropogenic sources (DER, 1988).

In order to establish baseline concentrations of heavy metals in estuarine sediments, the DER collected more than 100 sediment samples from "clean" coastal areas along the Atlantic and Gulf coasts of Florida. Metal concentrations were plotted against aluminum concentrations and individual regression lines and 95% confidence limits were calculated for arsenic, cadmium, chromium, copper, lead, nickel and zinc. The regression lines define the normal metal/aluminum relationship and the prediction limits indicate the range of concentrations found in natural sediments. If a particular metal concentration falls within the prediction limits, it is considered natural. When a point falls above the upper prediction limt, it indicates metal-enrichment. If data points fall below the lower prediction limit, then the analytical procedures should be evaluated for accuracy.

This interpretive tool can be used to compare metal concentrations within one estuary or between different water bodies. The tool can identify problem areas for continuous monitoring and can separate real from perceived or assumed problems. This technique can also be used to prioritize locations for bioassay research to measure the flux of metals back into the water column and estuarine food chain.

Description of Study Site

The Volusia County Environmental Management Department received a grant from DER to evaluate heavy metal concentrations in sediment near stormwater outfalls in Mosquito Lagoon. Three outfalls evaluated in Volusia County's 208 Water Quality Management Program were selected for this study (VCOG, 1980). These stormwater outfalls flow directly into Mosquito Lagoon. A background station was also included to verify the accuracy of the metal analysis. The background station was located east of spoil islands which protect the station from stormwater outfall influence (Figure 1).

The drainage basins for the New Smyrna Beach and Edgewater outfalls are developed. Single family residential areas are the predominant land use (Figures 2 & 3). The drainage basin for the Gabordy canal is primarily undeveloped and 81% of the land area is open space. The residential areas of this drainage basin are concentrated around the end of the canal (Figure 4). The size of each drainage basin and the types of land uses in each one is summarized in Table 1.

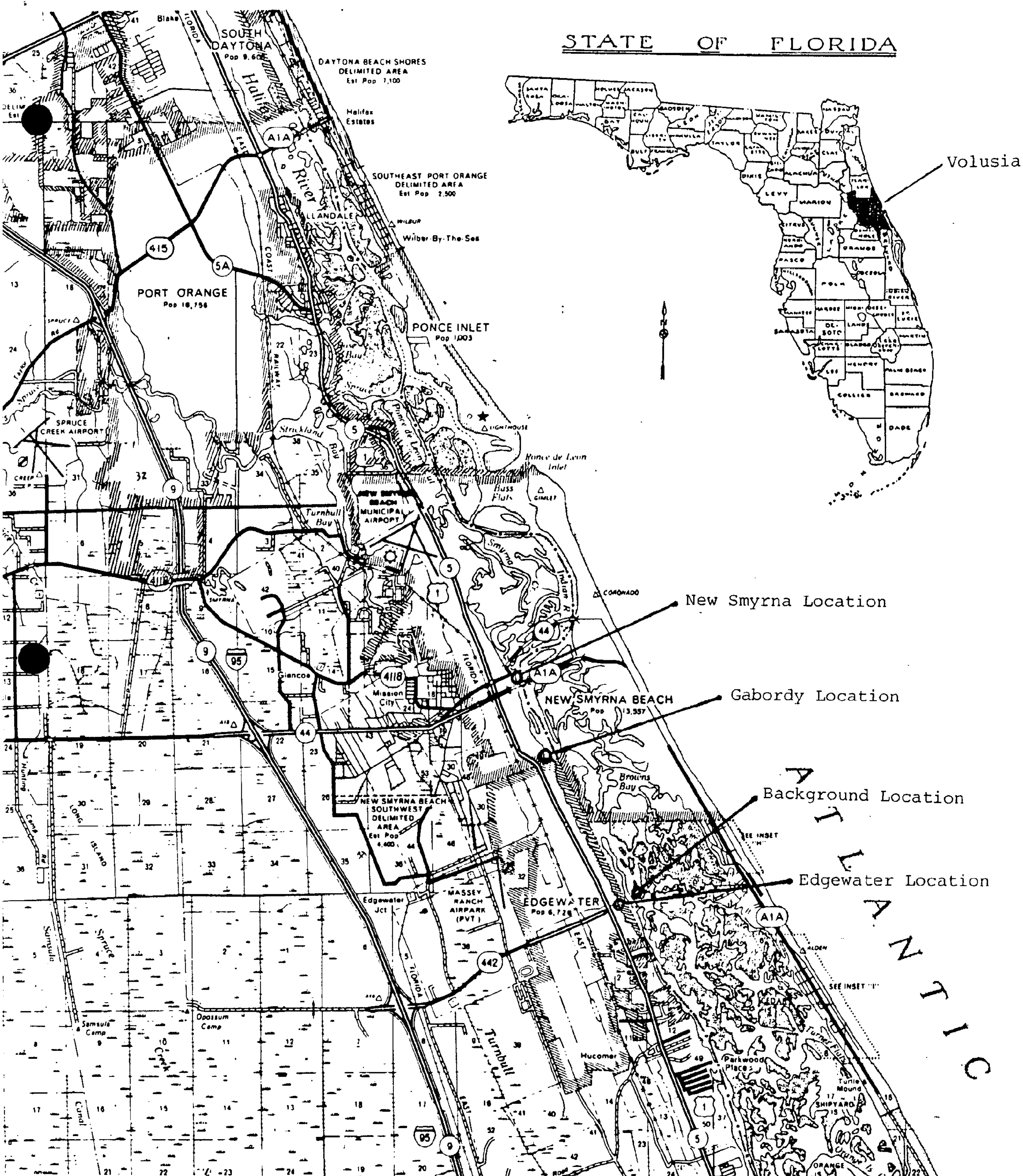


FIGURE 1. LOCATION OF MAJOR STORMWATER OUTFALLS AND BACKGROUND STATION IN MOSQUITO LAGOON.

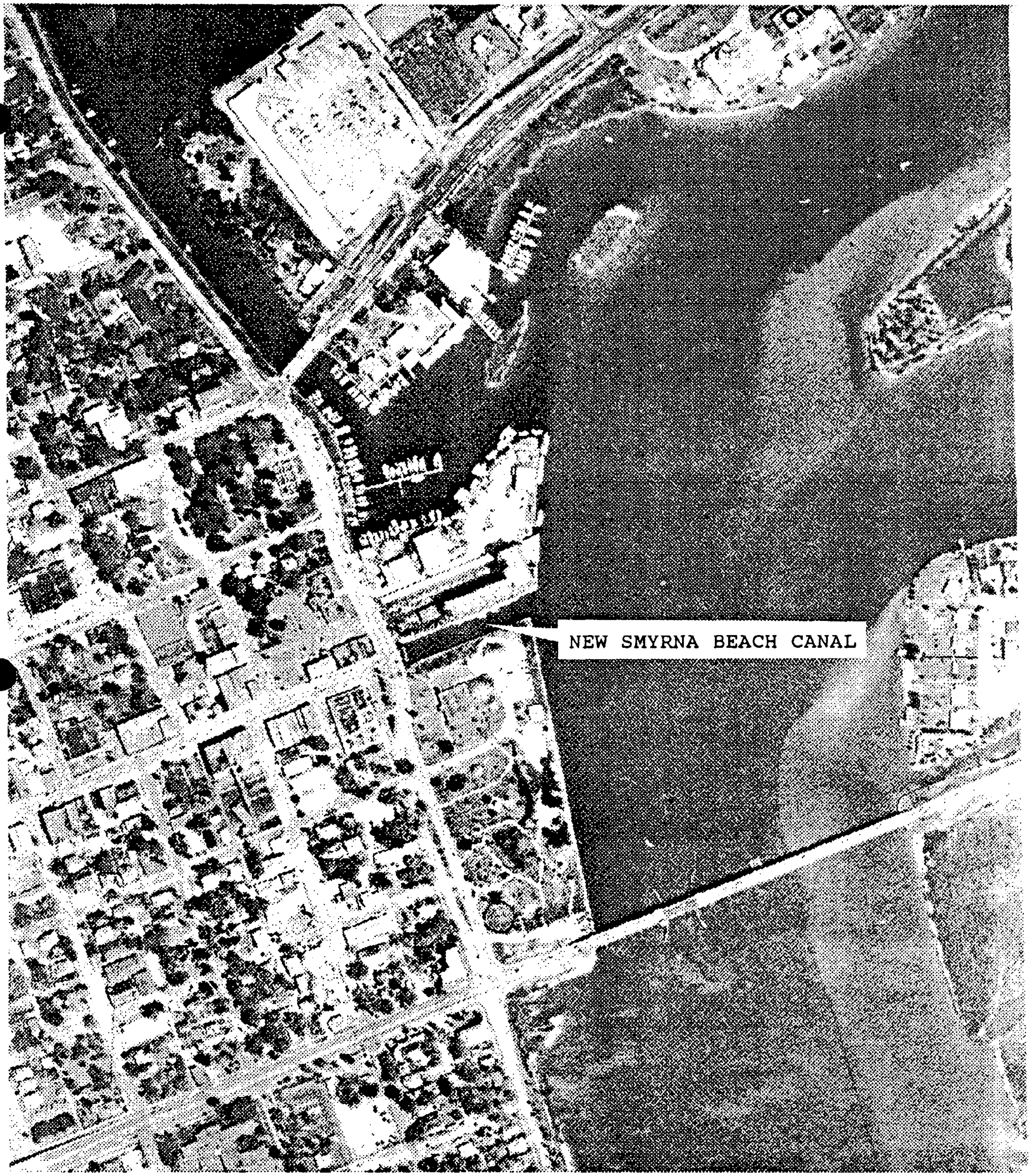
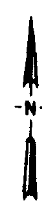


FIGURE 2. LOCATION MAP OF THE NEW SMYRNA BEACH DRAINAGE CANAL AND SURROUNDING AREA (SCALE 1"=400').



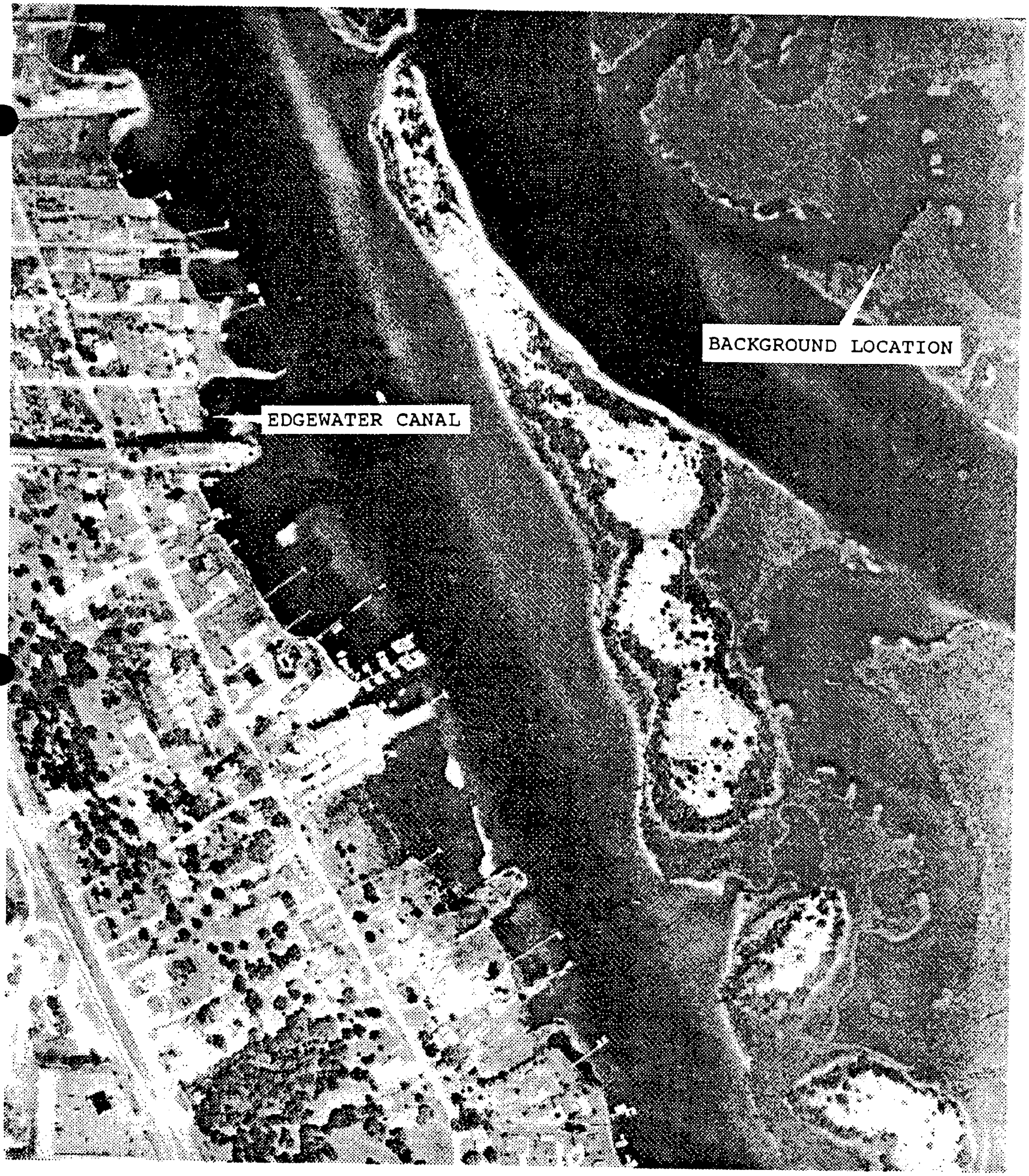


FIGURE 3. LOCATION MAP OF THE EDGEWATER DRAINAGE CANAL, BACKGROUND STATION, AND SURROUNDING AREA (SCALE 1"=400').

FIGURE 4. LOCATION MAP OF THE GABORDY DRAINAGE CANAL AND SURROUNDING AREA (SCALE 1"=400').

Outfall	Drainage Basin	Land Uses* (%) SF	C	R	OS	W
New Smyrna	418 acres	61	9	9	21	-
Gabordy	4129 acres	16	1.5	-	81	1.5
Edgewater	2519 acres	77	-	2	20	1

SF-Single Family, C-Commercial, R-Recreational, OS-Open Space, W-Water

Table 1. Characteristics of stormwater outfall drainage basins (Source: VCOG, 1980).

The main feature of the New Smyrna Beach outfall is a 8' x 6' box culvert which extends underneath the north sidewalk of S.R. 44. Stormwater is channelized directly to a concrete-walled canal with a boat dock for a condiminium complex along one side. The other two outfalls are open canals with vegetated banks. The Gabordy canal has a tree canopy which shades the water and prevents the growth of aquatic plants. The Edgewater canal is not shaded and fresh water plants, particularly water hyacinth (Eichhornia crassipes), duckweed (Lemna minor), coon tail (Ceratophyllum demersum) and hydrilla (Hydrilla verticillata), are abundant. An elevation drop of approximately two feet underneath Riverside Drive prevents tidal influence upstream of this point.

MATERIALS & METHODS

Three sampling sites were selected at the background and New Smyrna Beach stations and four sites were selected at the Gabordy and Edgewater canals (Figures 5-8). All of the sediment samples were collected using a twenty inch brass Wildco hand core sampler with clear CAB (cellulose-acetate-butyrate resin) liners. The top 10 cm of each core was transferred to an acid rinsed wide mouth glass jar with a screw cap. Triplicate samples were collected at each sampling site. Duplicate samples were prepared and analyzed while the triplicate samples were archived.

Excess water was poured off and the samples were homogenized. Approximately 1.5 g wet sample was placed in a teflon tube, 5 mL of hydrofluoric acid (49%) were added and the tubes were tightly capped. The samples were refluxed at 125 C for 48 hours in a block digester. The samples were then cooled and air dried in the block digester for 24 hours. Ten mL of aqua regia was added to each tube and the samples were heated for two hours. The samples were then filtered and diluted to 20 mL.

The samples were analyzed for arsenic, cadmium, chromium, copper, nickel and lead using atomic absorption (aa) furnace techniques. Aluminum and zinc were analyzed using aa flame techniques. Mercury analysis was performed by cold vapor technique. The percent total solids was determined through air drying of homogenized samples. All sample weights and

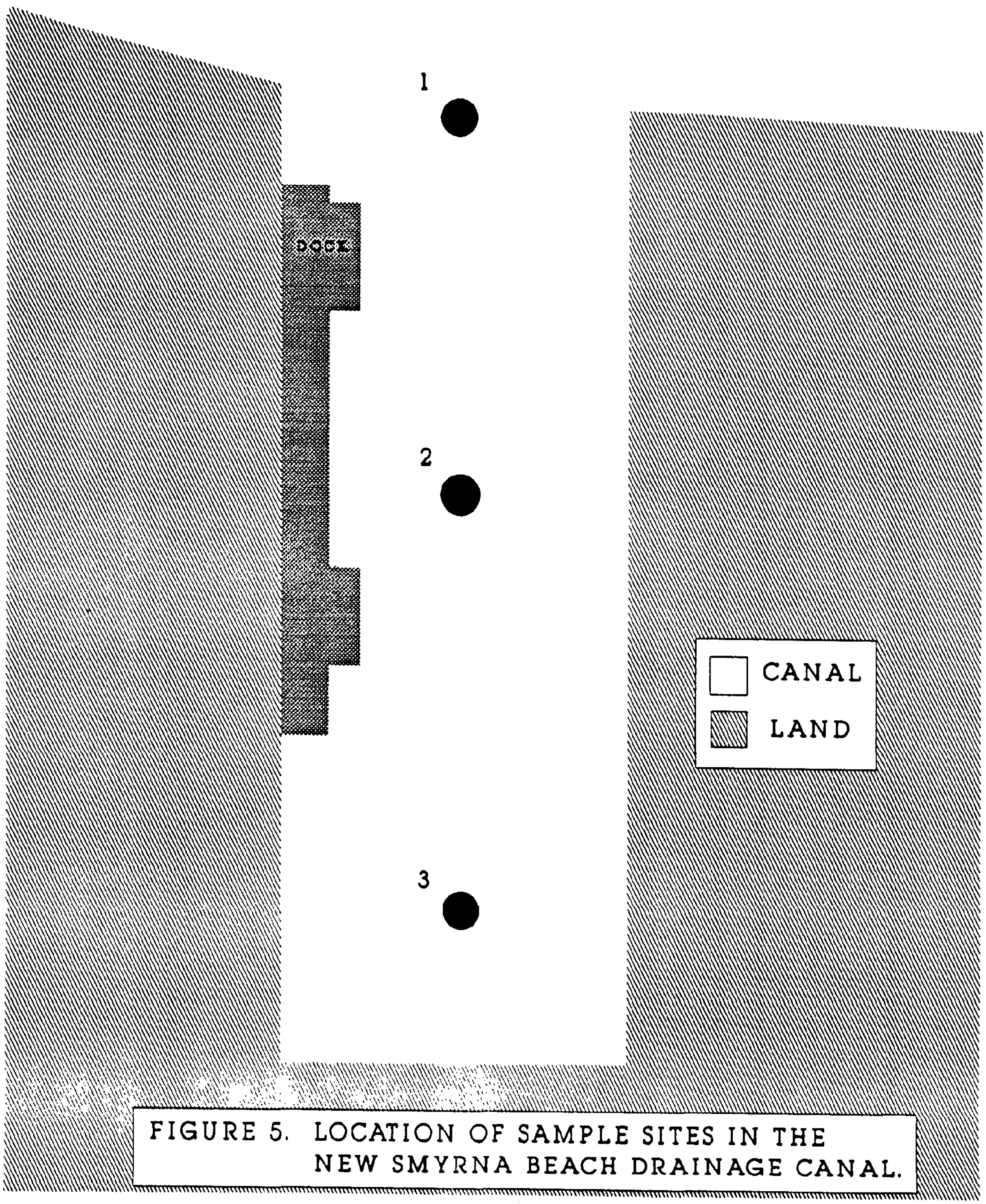


FIGURE 5. LOCATION OF SAMPLE SITES IN THE NEW SMYRNA BEACH DRAINAGE CANAL.

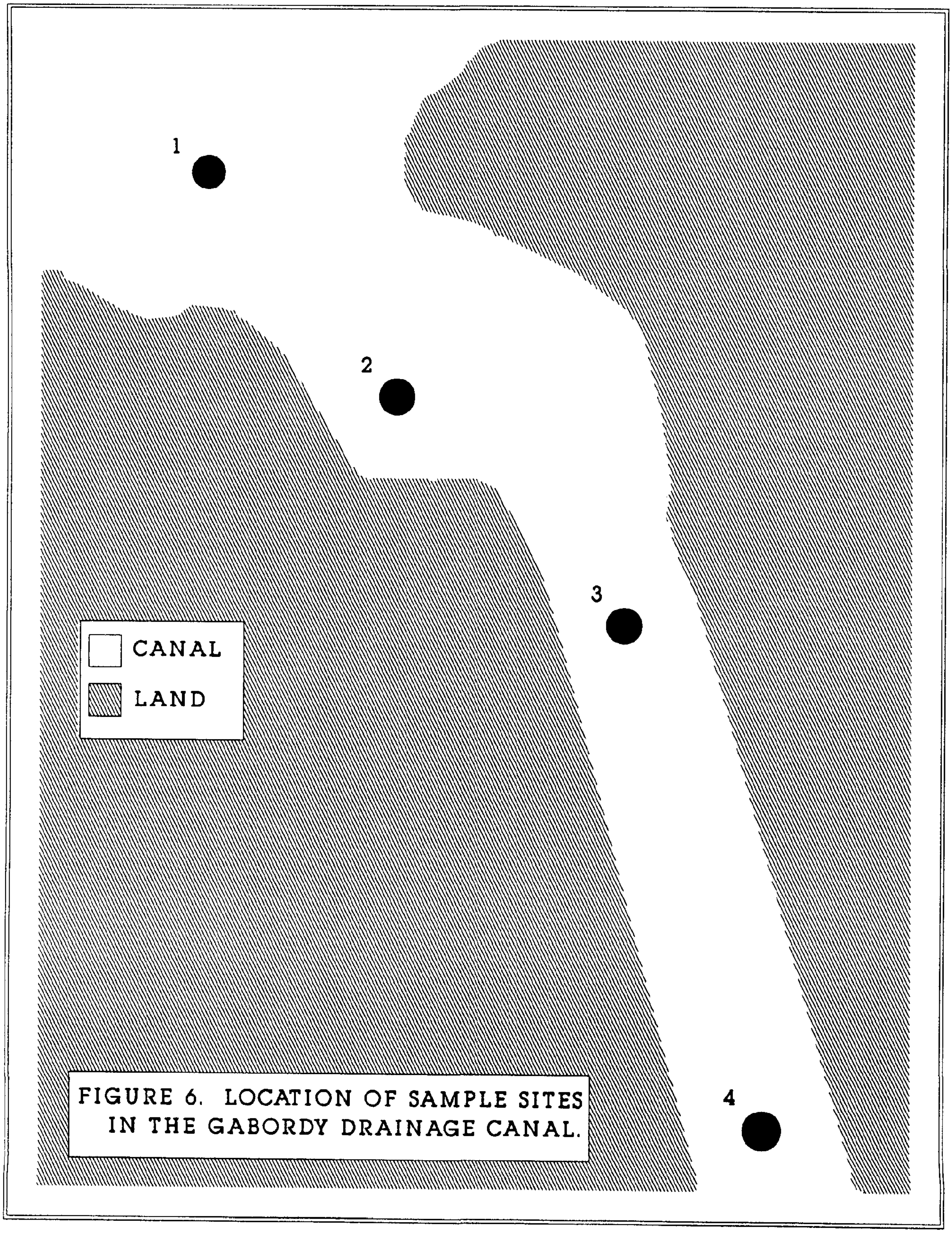


FIGURE 6. LOCATION OF SAMPLE SITES IN THE GABORDY DRAINAGE CANAL.

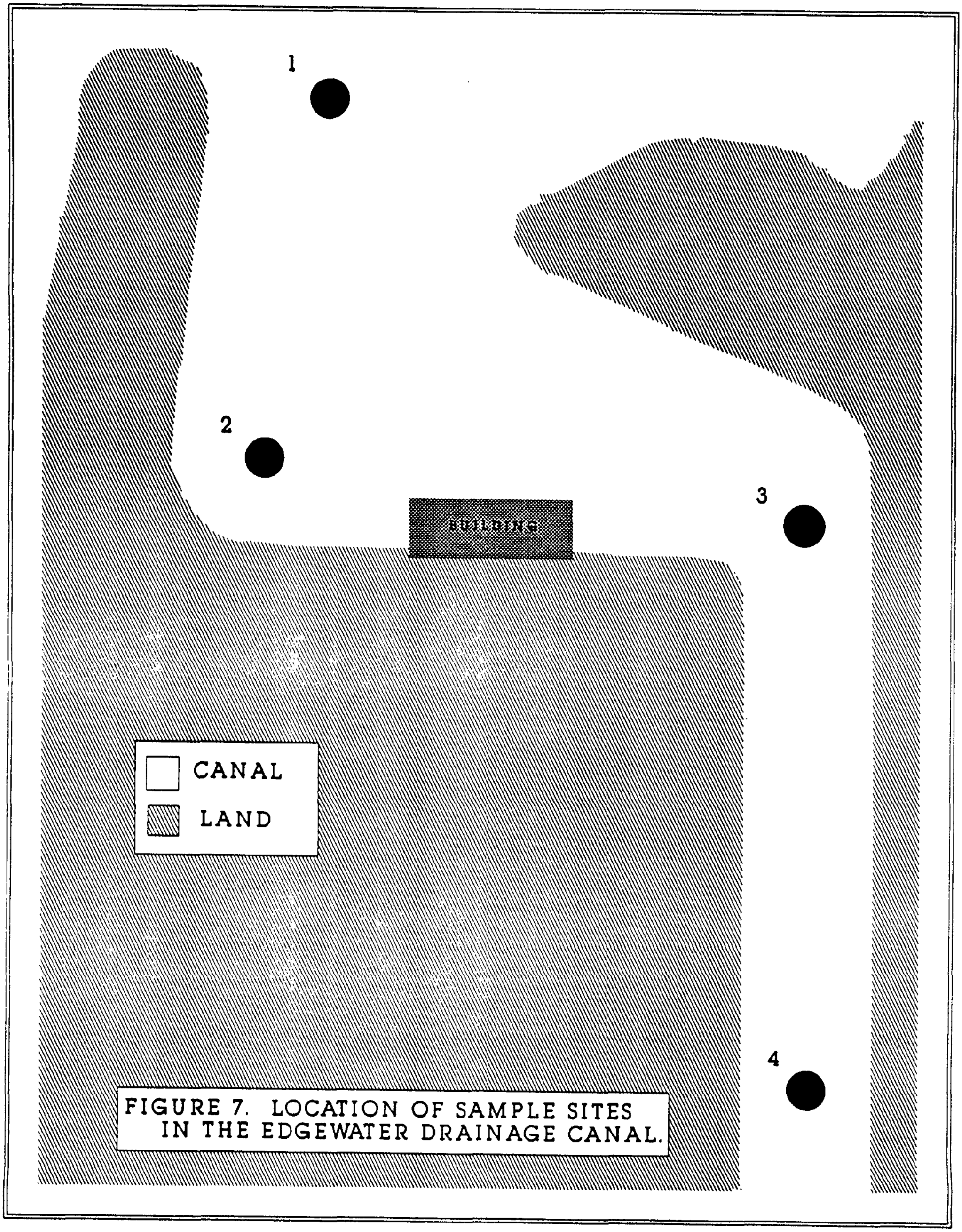


FIGURE 7. LOCATION OF SAMPLE SITES IN THE EDGEWATER DRAINAGE CANAL.

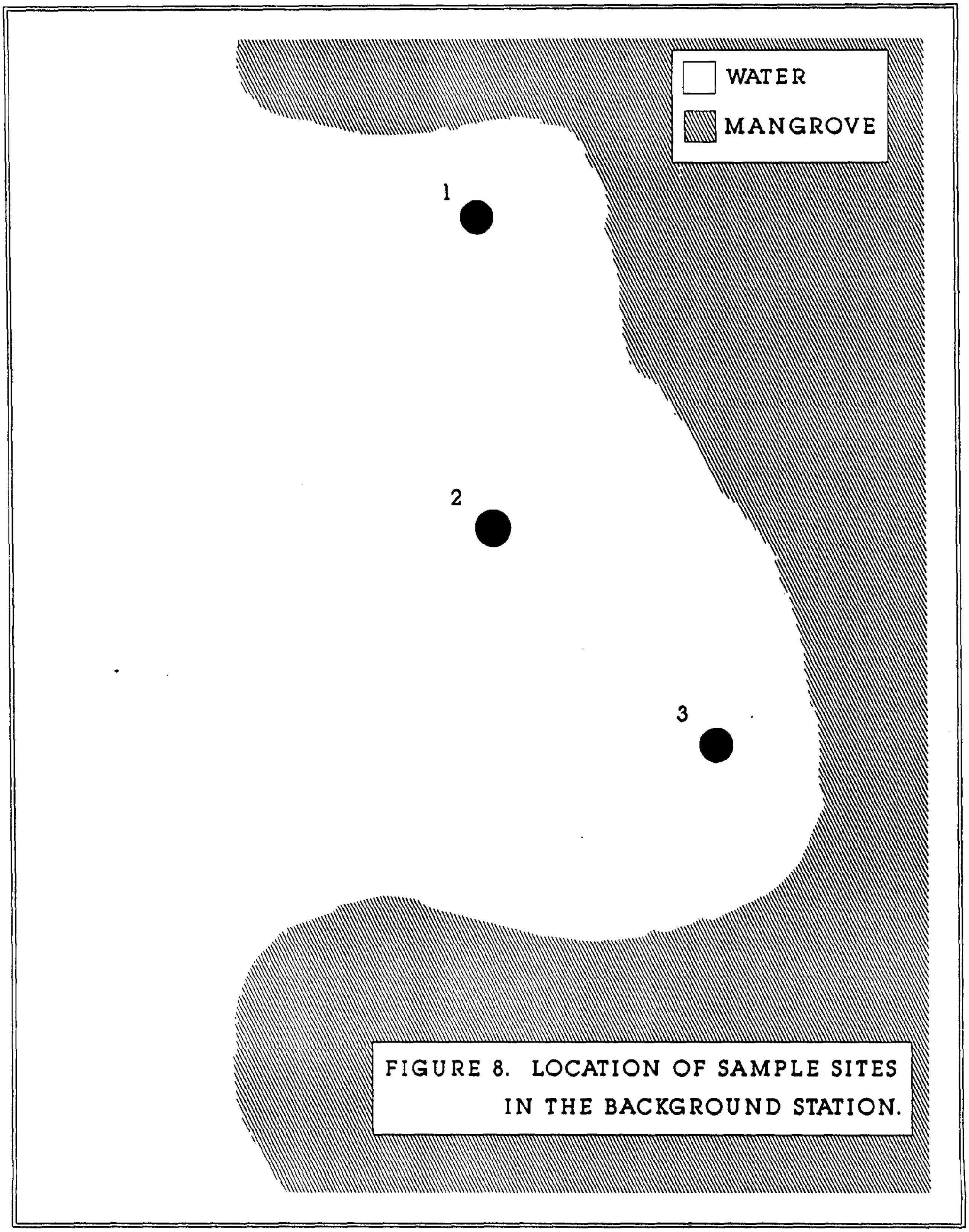


FIGURE 8. LOCATION OF SAMPLE SITES IN THE BACKGROUND STATION.

concentrations were recorded. The concentrations of all the metals except mercury were then plotted against the aluminum concentrations on the established curves.

The standard curves cannot be used for mercury because there is a weak inverse relationship with aluminum. Therefore, aluminum cannot be used as a reference element to determine natural vs. anthropogenic concentrations of mercury (DER, 1988). In order to evaluate mercury concentrations, DER suggested a threshold of 0.21 ppm, which was the highest concentration from the collection of "clean" sediments. Mercury concentrations well above this concentration could be considered enriched.

RESULTS

Sediment cores taken from two of the New Smyrna Beach canal stations were dominated by "muck", a fine-grained, organic sediment characterized by hydrogen sulfide generation. The samples taken in front of the box culvert outfall contained a mixture of muck, shell and gravel.

The cores taken from the Gabordy and Edgewater canals furthest downstream near the Indian River contained only sand or a mixture of sand and muck. The remaining cores taken from these canals were composed of muck except for those sampled from the Edgewater canal furthest upstream which contained a mixture of muck and shell. The sediment cores at the background station contained a mixture of oyster shell and muck.

The aluminum concentrations from all of the sediment cores fell within the range of 47 - 79,000 ppm required to use the metal/aluminum standard curves. The mean concentrations for all nine metals at each location are listed in Table 2.

Location	New Smyrna	Gabordy	Edgewater	Background
# of samples	6	8	8	6
Aluminum	12,067	8,813	9,350	7,383
Arsenic	4.0	1.0	1.8	3.9
Cadmium	0.304	0.058	0.077	0.044
Chromium	37	20	1.86	27
Copper	27 *	6	6.1	3.8
Lead	144 *	15 *	15 *	8.3
Mercury	0.28	0.20	0.24	0.24
Nickel	6.4	2.6	3.6	4.3
Zinc	154 *	29	42 *	23

Table 2. Mean metal concentration (ppm) for each location within the Indian River/Mosquito Lagoon. (*) indicates mean concentration exceeds 95% prediction limits.

The concentrations of arsenic, cadmium and chromium fell within, or very close to, the expected range for natural sediments at all four locations (Figures 9-11). Nickel concentrations also fell within the natural range at the background and New Smyrna Beach canal stations. Six cores from the Gabordy and Edgewater canals had nickel concentrations below the lower prediction limit (Figure 12).

Copper concentrations at the background station, Gabordy canal and Edgewater canal fell within the prediction limits. Four cores from the New Smyrna Beach canal had copper concentrations above the upper prediction limit (Figure 13).

Several zinc concentrations at all four stations were above the upper prediction limit (Figure 14). The mean concentration of zinc fell within the range at the Gabordy and background stations and above the range at the New Smyrna Beach and Edgewater stations. The cores taken furthest upstream in the Edgewater and New Smyrna Beach canals had zinc concentrations well above the upper prediction limit.

Lead concentrations fell above the natural range at all four stations (Figure 15). The mean concentration of lead fell within the expected range at the background station, slightly above the range at the Gabordy and Edgewater canals and well above the range at New Smyrna Beach. Lead concentrations were highest in the cores taken near the outfall in the New Smyrna Beach canal. The mean concentration from this outfall was eighteen times greater than the mean at the background station.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - ARSENIC

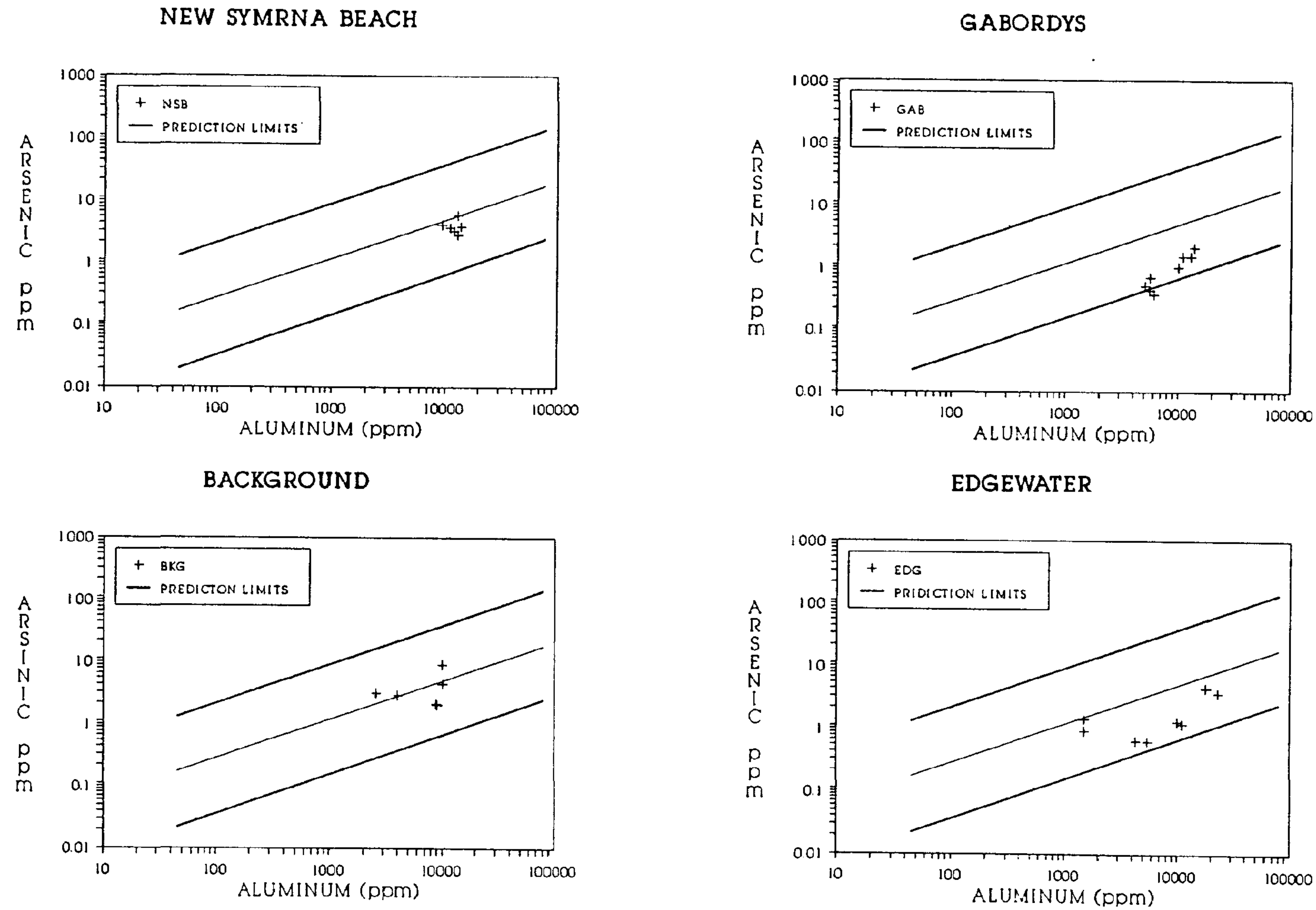


FIGURE 9. INDIAN RIVER LAGOON ARSENIC/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - CADMIUM

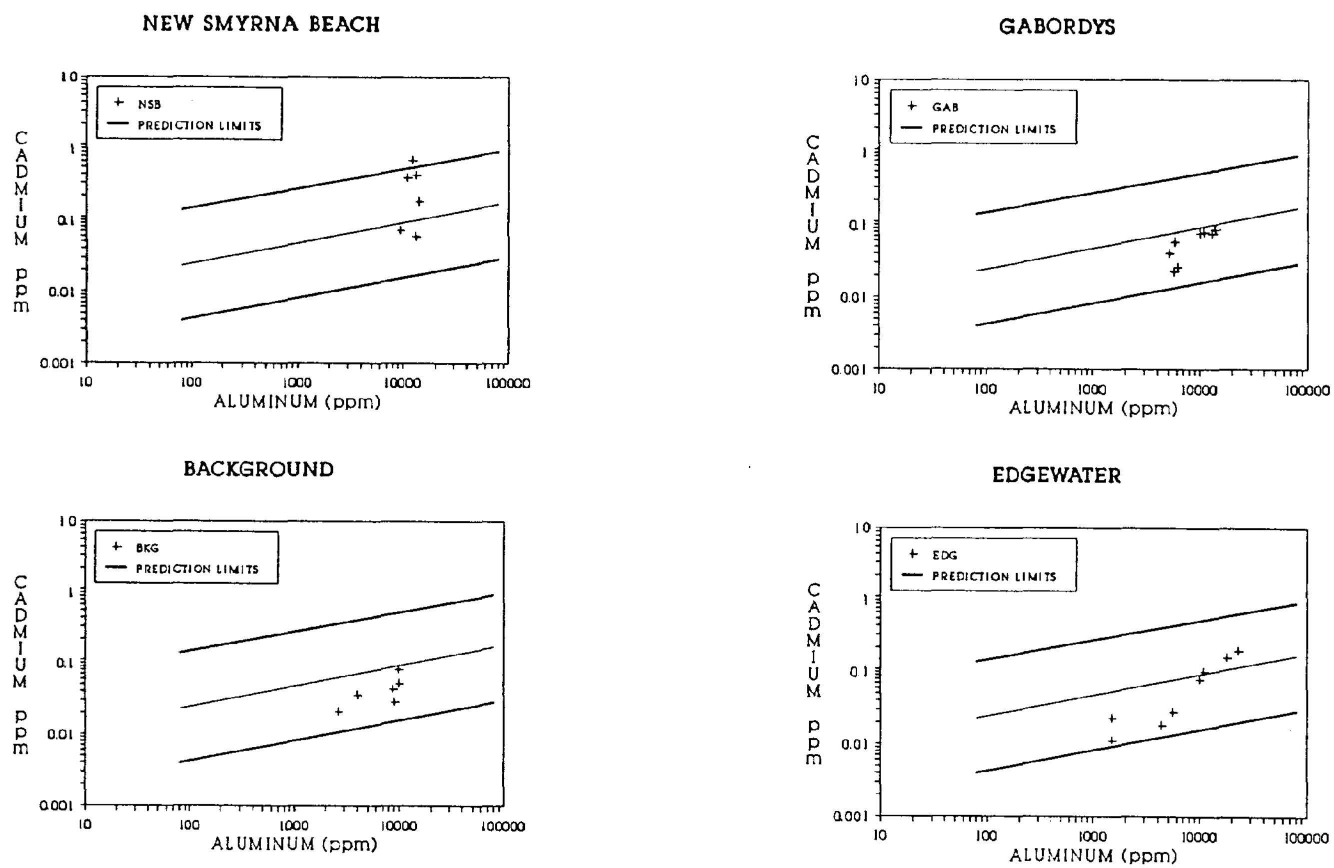


FIGURE 10. INDIAN RIVER LAGOON COPPER/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - CHROMIUM

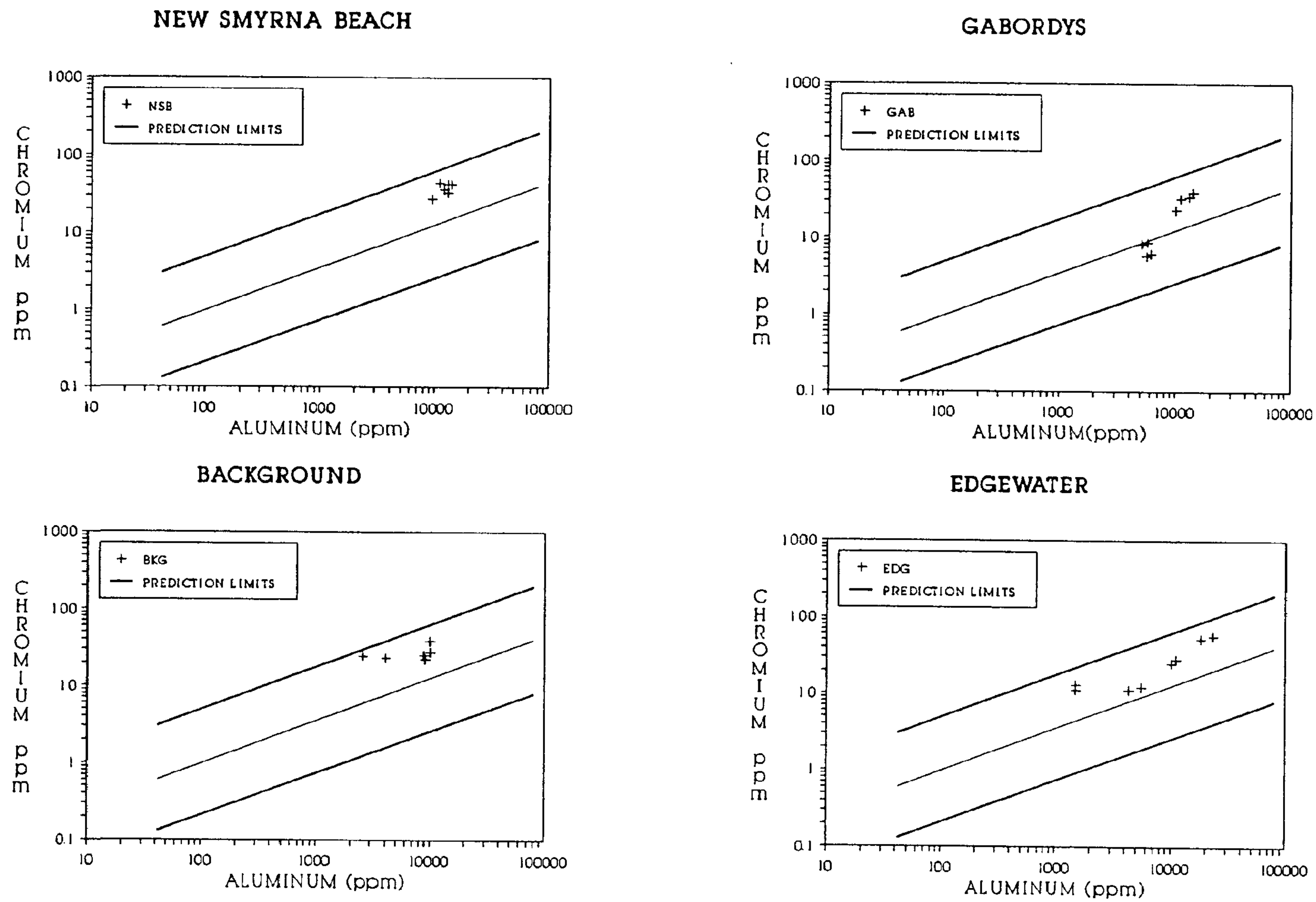


FIGURE 11. INDIAN RIVER LAGOON CHROMIUM/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - NICKEL

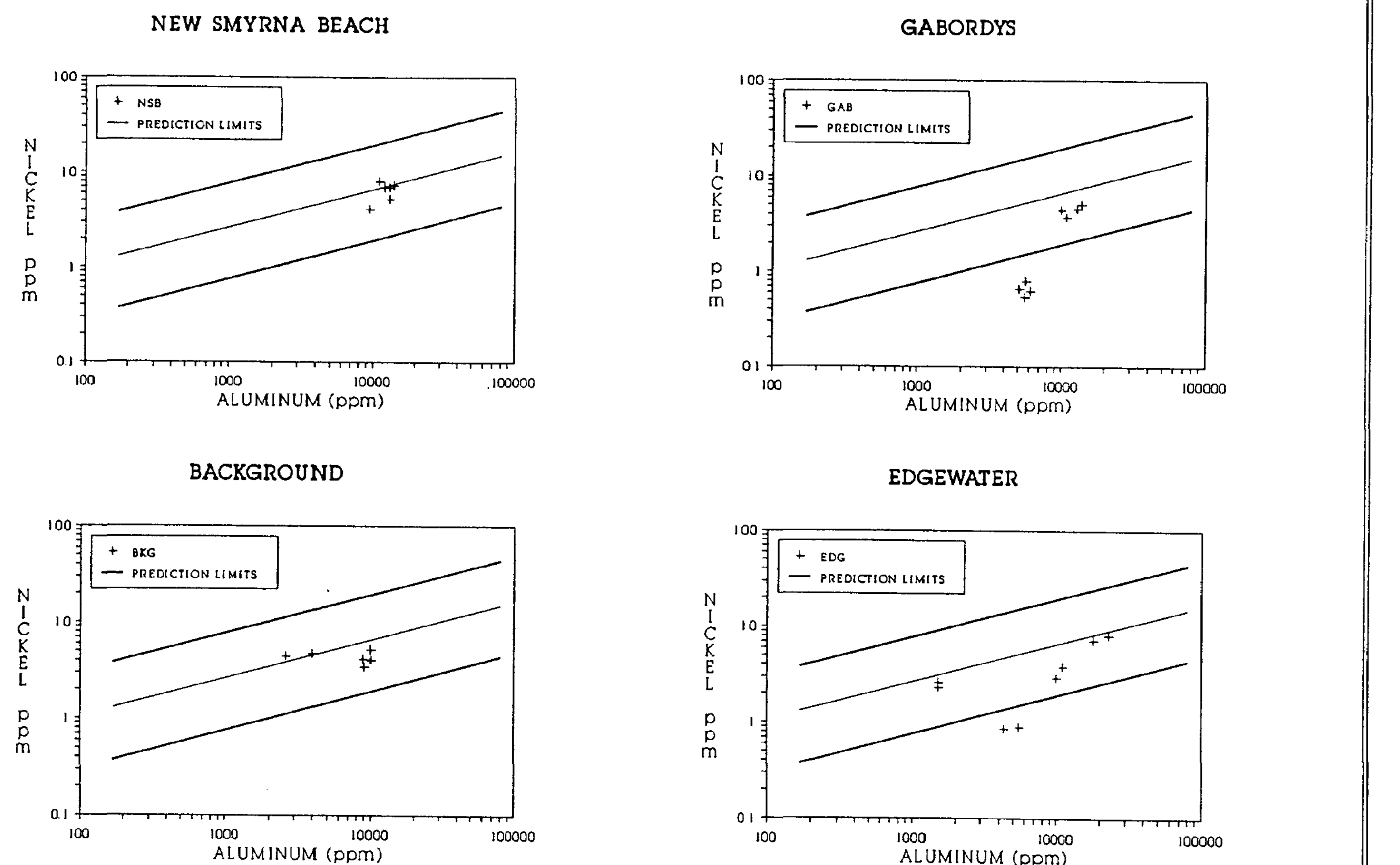


FIGURE 12. INDIAN RIVER LAGOON NICKEL/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - COPPER

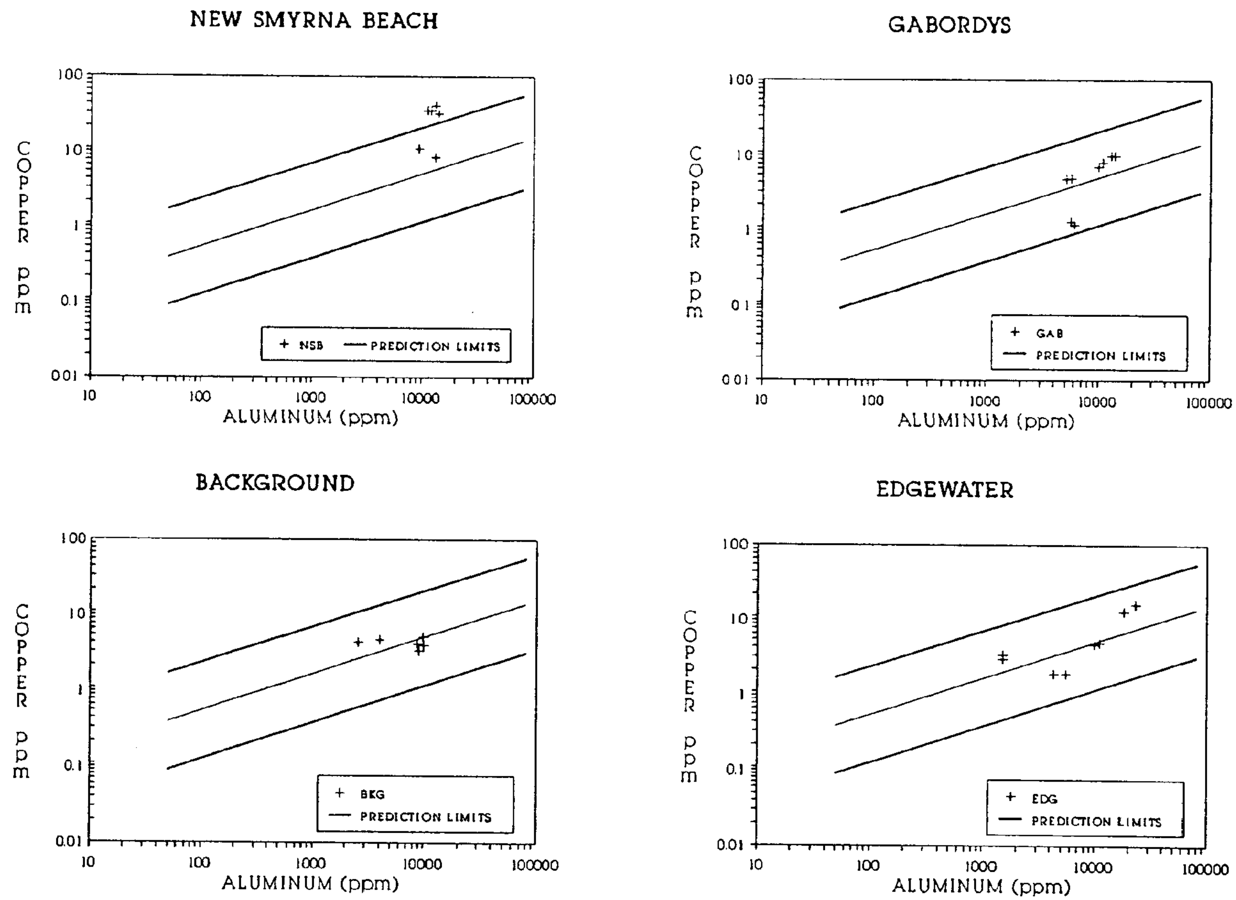


FIGURE 13. INDIAN RIVER LAGOON COPPER/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - ZINC

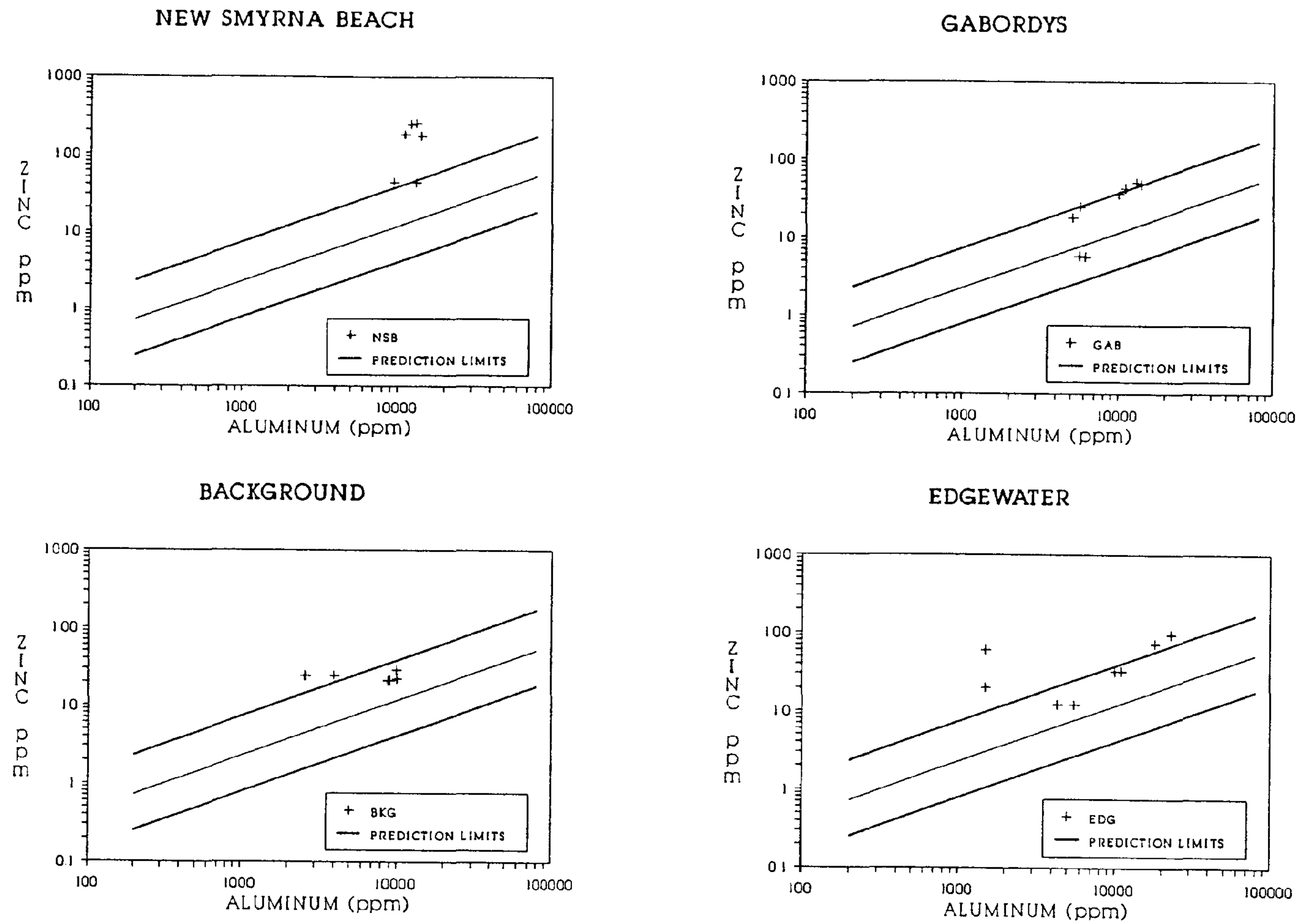


FIGURE 14. INDIAN RIVER LAGOON ZINC/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

INDIAN RIVER LAGOON
SEDIMENT ANALYSIS - LEAD

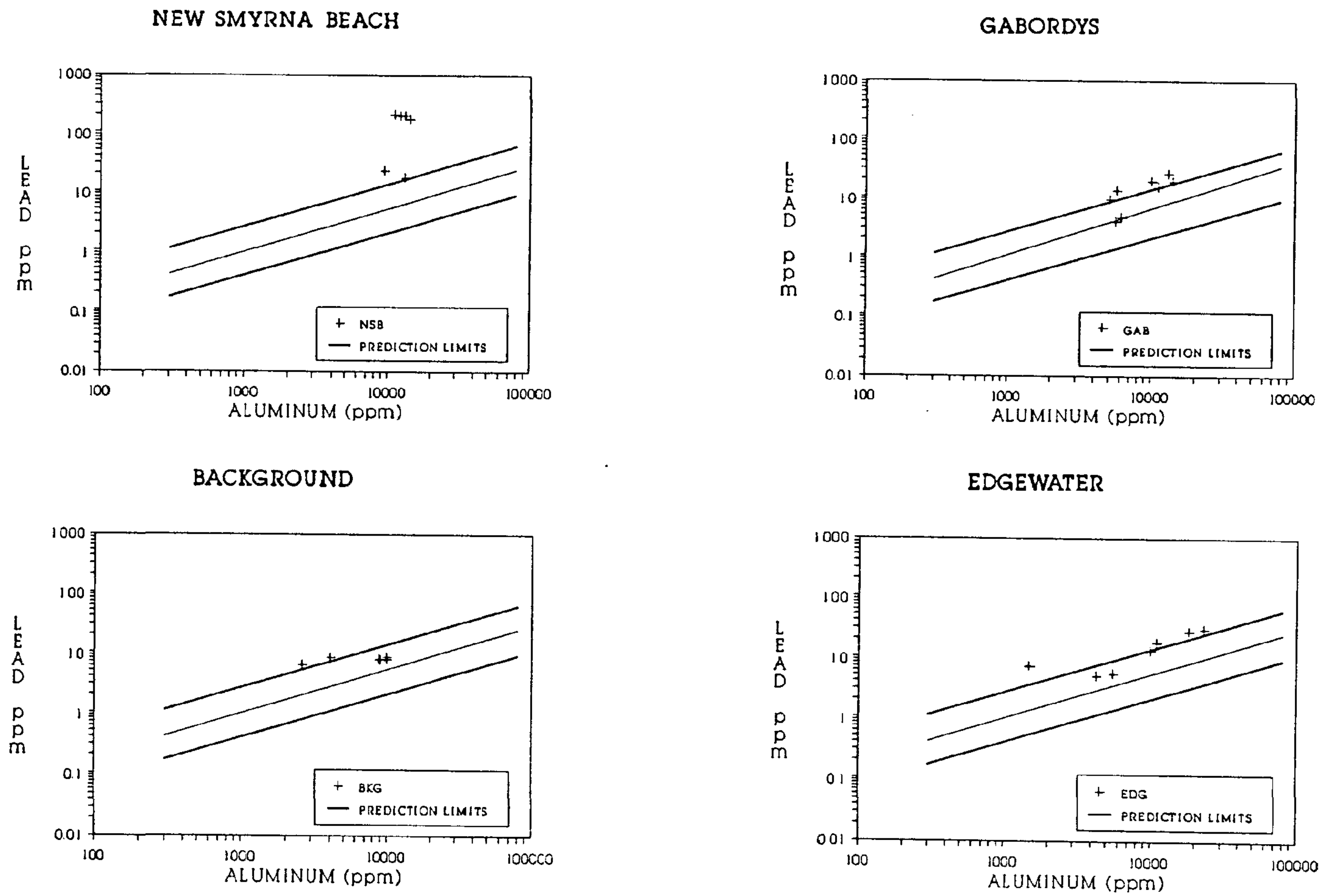


FIGURE 15. INDIAN RIVER LAGOON LEAD/ALUMINUM CONCENTRATIONS WITH PREDICTED LIMITS (95%) FOR NATURAL SEDIMENTS.

The mean concentrations of mercury from all four locations were close to the threshold of 0.21 ppm. The highest mercury levels were in the Edgewater canal (0.44 & 0.47 ppm). Elevated mercury concentrations were also found in four cores from the New Smyrna Beach canal (0.27-0.37 ppm), in three cores from the Gabordy canal (0.26-0.28 ppm) and in two cores from the background station (0.28 & 0.33 ppm).

DISCUSSION

The majority of the heavy metals analyzed in this study fell within the expected range for clean estuarine sediments. Even those metal concentrations which fell slightly above the upper limit could be considered natural because of the confidence limit established for the standard curves.

A rough comparison was made between the background metal concentrations in this study and those collected by DER in 1985. Background concentrations of cadmium, copper, arsenic and nickel in this study were less than or equal to DER's samples. Concentrations of lead, zinc and chromium in this study were greater than DER's samples, yet still within the expected range.

Apparent heavy metal enrichment was found in the New Smyrna Beach canal. Elevated concentrations of copper, lead and zinc were found. Concentrations were greatest near the outfall and decreased towards the Indian River, although the sample farthest from the outfall also showed enrichment. This heavy metal loading is probably due to the developed character of the drainage basin and the channelized flow of stormwater into the canal.

Heavy metal concentrations in the other two outfalls were generally lower than in the New Smyrna Beach outfall, yet there were elevated concentrations of metals in both the Edgewater and Gabordy canals. Lower concentrations in these canals is probably due to entrapment of sediments by rooted vegetation upstream of the sampling sites.

There was apparent enrichment of lead and zinc in the Gabordy canal. The degree of enrichment is slight because the elevated concentrations were just over the upper prediction limit. Even though the drainage basin of the Gabordy canal is primarily undeveloped, stormwater runoff from residential areas adjacent to the outfall of this canal apparently includes heavy metals.

The Edgewater canal sediments were also enriched with lead and zinc. Even though the drainage basin of the Edgewater canal is more developed, the heavy metal concentrations were not much higher than those found in the Gabordy canal. The major freshwater input to this canal is surficial groundwater from the Florida Shores subdivision. Many of the roads in this residential area are unpaved. The only major stormwater input to the Edgewater canal is a large shopping center on U.S. 1 near the outfall of the canal.

The highest concentrations of several metals in the Gabordy and Edgewater canals were found at the second and third sampling sites. When stormwater flows around the curves in these outfalls, the velocity is reduced allowing fine-grained sediments with adsorbed metals to settle from the water column. The lowest metal concentrations were found near the Indian River. Strong north-south tidal currents at the end of all three outfalls probably carry the remaining suspended sediments from the area. If the stormwater drainage systems can be modified with meanders for solid deposition, most of the heavy metals could be removed before the discharge reaches Mosquito Lagoon.

The mercury concentrations in this study were approximately six times greater than the levels found by DER. Even though the recommended threshold was surpassed, the data in this study do not indicate mercury enrichment from stormwater because the background station also had an elevated concentration. The results indicate either increasing mercury concentrations throughout Mosquito Lagoon or possibly the use of different analytical procedures. There are no known sources of mercury in Volusia County from commercial or industrial discharges (Anderson, 1989). Further analysis of mercury in the sediments is needed to draw definite conclusions.

While the degree of metal enrichment in these stormwater outfalls is not severe, there is potential for the metals to reach the estuarine food chain. Several research projects have identified elevated metal concentrations in barnacles, clams and blue crabs caught in harbors with enriched sediments (Windsor, 1983). The Class II shellfish beds in Mosquito Lagoon are probably not threatened at this time because they are removed from major urban areas.

Mobile organisms, such as blue crabs, can spread metal contamination. In 1980, one hundred large red drum in Mosquito Lagoon were killed by copper, zinc and arsenic (Delfino et al., 1984). The source of the metals was never traced, although it was assumed the fish ate contaminated blue crabs. Since this was an isolated incident, the heavy metals may have originated from a particular event, such as channel or marina dredging. Dredging projects within the Class II area should be monitored for heavy metal resuspension.

This sediment study attempted to identify and quantify only one component of stormwater pollution at the receiving water body. The results of this study illustrate the need to further assess heavy metal contamination upstream of the estuary and other pollutant loadings from the stormwater drainage systems discharging into Mosquito Lagoon.

An investigation should be undertaken within each drainage system to identify the type, quantity, and source distribution of pollutants during storm events and normal flow conditions. Since the Garbody and Edgewater canals are vegetated with rooted and floating plants, the effectiveness of pollutant removal by the aquatic vegetation and the impacts of aquatic plant control should also be investigated. The information that would be obtained from a comprehensive program of this type may provide valuable data to determine the most effective design of the various methods of stormwater abatement.

REFERENCES

Anderson, L. 1989. Personal communication. Volusia County Environmental Management Department, Division of Pollution Control.

Burke, R. 1977. Stormwater Runoff. In J.R. Clark (Ed.), Coastal Ecosystem Management, 1983, Robert E. Krieger Publishing Company, Inc., pp. 727-733.

Department of Environmental Regulation. 1988. A Guide to the Interpretation of Metal Concentrations in Estuarine Sediments.

Delfino, J.J., D.L. Frazier, J.L. Nepshinsky. 1984. Contaminants in Florida's coastal zone: A review of present knowledge and proposed research strategies. Florida Sea Grant Report No. 62, University of Florida, Gainesville, Florida.

Martin, J., and M. Whitfield. 1983. The Significance of the River Input of Chemical Elements to the Ocean. In C.S. Wong, E. Boyle, K. Bruland, J.D. Burton and E. Goldberg (Eds.), Trace Metals in Sea Water, 1983, Plenum Press, pp.265-296.

Surface Water Improvement and Management (SWIM) Plan for Indian River Lagoon. 1989. St. Johns River and South Florida Water Management Districts.

Trefry, J., M. Sadoughi, M.D. Sullivan, J.S. Steward and S. Barber. 1983. Trace metals in the Indian River Lagoon, Florida: The Copper Story. Florida Scientist 46: 415-427.

Volusia Council of Governments (VCOG). 1980. 208 Water Quality Management Program, volume 3 of 3.

Windsor, J. 1987. Water and Sediment Quality. In J.S. Steward and J.A. VanArman (Eds.), Indian River Lagoon Joint Reconnaissance Report, 1987, pp.5-1 thru 5-58.